

CLAIMS

1. Method of sending an original information sequence, including:

- an encoding operation (E1), consisting of encoding said original

5 information sequence by means of an error correction code, so as to obtain a sequence of encoded symbols;

- a frequency mapping operation (E2), consisting of associating with the sequence of encoded symbols K frequency symbols in a frequency space consisting of an ordered series of  $2^p$  increasing frequencies, periodically spaced 10 apart and associated with an amplitude, each of said K frequency symbols representing N encoded symbols, p, K and N being strictly positive integers;

- an inverse transformation operation (E3), consisting of applying to the K frequency symbols a reversible transformation including a multiplication by an invertible matrix of size  $N \times N$ , so as to obtain inverse transform signals;

15 and

- a transmission operation (E4), consisting of sending over a transmission channel signals obtained from said inverse transform signals;

characterised in that there exists a K-tuplet of positive integers  $n_1, n_2, \dots, n_K$ , at least one of which is strictly positive, such that, for an integer  $i$  varying from 1 to

20 K, after periodic extraction of one frequency out of  $2^{n_i}$  amongst the frequencies of the  $i^{\text{th}}$  of said K frequency symbols, thus forming a reduced frequency symbol with  $2^{p-n_i}$  frequencies, a set of K reduced frequency symbols is obtained, representing said original information sequence, with a view to a complete or partial decoding.

25 2. Sending method according to Claim 1, characterised in that there exists a strictly positive integer  $n$  such that, after periodic extraction of one frequency out of  $2^n$  amongst the frequencies of each of said K frequency symbols, thus forming a reduced frequency symbol with  $2^{p-n}$  frequencies, there is obtained a set of K reduced frequency symbols representing said original 30 information sequence.

3. Sending method according to Claim 1 or 2, characterised in that said encoding operation (E1) includes at least one systematic recursive convolutional encoding operation.

4. Sending method according to Claim 1, ~~2 or 3~~, <sup>082</sup> characterised in that said encoding operation (E1) is a turbo-encoding operation.

5. Sending method according to ~~any of the preceding claims~~, <sup>1082</sup> characterised in that said reverse transformation operation (E3) is an inverse fast discrete Fourier transformation operation.

6. Sending method according to ~~any of the preceding claims~~, <sup>1082</sup> in which said original information sequence has a length  $\ell$ , characterised in that a value of N is chosen which is both a power of 2 and equal to  $4\ell$ .

7. Sending method according to ~~any of the preceding claims~~, <sup>1082</sup> characterised in that said encoding operation (E1) is a turbo-encoding operation with two parities and, during said frequency mapping operation (E2), for each block of four successive frequencies, corresponding respectively to four sub-carriers:

- the systematic output (x) obtained at the end of the turbo-encoding operation is associated with the first available sub-carrier, in the sense of the lowest frequency in the block;

- the output with the second parity ( $y_2$ ) obtained at the end of the turbo-encoding operation is associated with the second sub-carrier in the block;

- the output with the first parity ( $y_1$ ) obtained at the end of the turbo-encoding operation is associated with the third sub-carrier in the block; and

25 - the systematic output (x) is also associated with the fourth available sub-carrier, in the sense of the highest frequency in the block.

8. Sending method according to ~~any of Claims 1 to 6~~, <sup>082</sup> characterised in that said encoding operation (E1) is a turbo-encoding operation with three parities and in that, during said frequency mapping operation (E2), for each block of four successive frequencies, corresponding respectively to four sub-carriers:

- the systematic output (x) obtained at the end of the turbo-encoding operation is associated with the first available sub-carrier, in the sense of the lowest frequency in the block;

5 - the output with the second parity (y2) obtained at the end of the turbo-encoding operation is associated with the second sub-carrier in the block;

- the output with the first parity (y1) obtained at the end of the turbo-encoding operation is associated with the third sub-carrier in the block; and

10 - the output with the third parity (y3) obtained at the end of the turbo-encoding operation is associated with the fourth available sub-carrier, in the sense of the highest frequency in the block. *1022*

9. Sending method according to any of the preceding claims characterised in that it uses a modulation of the OFDM type.

10. Device for sending an original information sequence, having:

- encoding means (30; 90), for encoding said original information

15 sequence by means of an error correction code, so as to obtain a sequence of coded symbols;

- frequency mapping means (32; 92), for associating with said sequence of encoded symbols K frequency symbols in a frequency space consisting of an ordered sequence of  $2^p$  increasing frequencies periodically spaced apart and associated with an amplitude, each of said K frequency symbols representing N encoded symbols, p, K and N being strictly positive integers;

- inverse transformation means (34; 94), for applying to said K frequency symbols a reversible transformation including a multiplication by an invertible matrix with a size  $N \times N$ , so as to obtain inverse transform signals; and

- transmission means (36; 96), for sending over a transmission channel signals obtained from said inverse transform signals;

characterised in that there exists a K-tuplet of positive integers  $n_1, n_2, \dots, n_K$ , at least one of which is strictly positive, such that, for an integer i varying from 1 to

30 K, after periodic extraction of one frequency out of  $2^{n_i}$  amongst the frequencies of the  $i^{\text{th}}$  of said K frequency symbols, thus forming a reduced frequency symbol with  $2^{p-n_i}$  frequencies, a set of K reduced frequency symbols is obtained,

representing said original information sequence, with a view to a complete or partial decoding.

11. Sending device according to Claim 10, characterised in that there exists a strictly positive integer  $n$  such that, after periodic extraction of one frequency out of  $2^n$  amongst the frequencies of each of said  $K$  frequency symbols, thus forming a reduced frequency symbol with  $2^{p-n}$  frequencies, there is obtained a set of  $K$  reduced frequency symbols representing said original information sequence.

12. Sending device according to Claim 10 or 11, characterised in that said encoding means (30; 90) include at least first systematic recursive convolutional encoding means.

*a* 13. Sending device according to Claim 10, <sup>or 12</sup> ~~11 or 12~~, characterised in that said encoding means (30; 90) are turbo-encoding means.

*a* 14. Sending device according to ~~any of Claims~~ 10 <sup>or 11</sup> ~~to 13~~, characterised in that said reverse transformation means (34; 94) are inverse fast discrete Fourier transformation means.

*a* 15. Sending device according to ~~any of Claims~~ 10 <sup>or 11</sup> ~~to 14~~, in which said original information sequence has a length  $\ell$ , characterised in that, for said predetermined number (N), a value is chosen which is both a power of 2 and equal to  $4\ell$ .

*a* 16. Sending device according to ~~any of Claims~~ 10 <sup>or 11</sup> ~~to 15~~, characterised in that said encoding means (30) are turbo-encoding means with two parities and in that said frequency mapping means (32) associate, for each block of four successive frequencies, corresponding respectively to four sub-carriers:

- the systematic output (x) of the turbo-encoding means with the first available sub-carrier, in the sense of the lowest frequency in the block;
- the output with the second parity (y2) of the turbo-encoding means with the second sub-carrier in the block;
- the output with the first parity (y1) of the turbo-encoding means with the third sub-carrier in the block; and

- the systematic output (x) also with the fourth available sub-carrier, in the sense of the highest frequency in the block.

17. Sending device according to any of Claims 10 to 15, characterised in that said encoding means (90) are turbo-encoding means with three parities and in that said frequency mapping means (92) associate, for each block of four frequencies, corresponding respectively to four sub-carriers:

- the systematic output (x) of the turbo-encoding means with the first available sub-carrier, in the sense of the lowest frequency in the block;

- the output with the second parity (y2) of the turbo-encoding means with the second sub-carrier in the block;

- the output with the first parity (y1) of the turbo-encoding means with the third sub-carrier in the block; and

- the output with the third parity (y3) of the turbo-encoding means with the fourth available sub-carrier, in the sense of the highest frequency in the block.

18. Sending device according to any of Claims 10 to 17, characterised in that it uses a modulation of the OFDM type.

19. Method of receiving signals representing an original information sequence sent by means of a transmission method according to any one of Claims 1 to 9, characterised in that, from a K-tuplet of granularity equal to positive integers  $n'_1, n'_2, \dots, n'_K$  such that each integer  $n'_i$  is less than or equal to said integer  $n_i$ , said reception method includes:

- an operation of receiving K frequency symbols sent by means of said transmission method;

25 - an extraction operation consisting, for each integer  $i$  varying from 1 to K, of periodically extracting one frequency out of  $2^{n'_i}$  amongst the frequencies of the  $i^{\text{th}}$  of said K frequency symbols received, thus forming a reduced frequency symbol with  $2^{p-n'_i}$  frequencies;

30 - a transformation operation (E6; E10; E14) consisting, for each integer  $i$  varying from 1 to K, of applying to said reduced frequency symbol with  $2^{p-n'_i}$  frequencies, a reversible transformation including a multiplication by an invertible matrix of size  $2^{p-n'_i} \times 2^{p-n'_i}$ ; and

- an operation of decoding (E8; E12; E16) all the K reduced frequency symbols with  $2^{p-n'}$  frequencies, thus forming a decoded information sequence.

20. Reception method according to Claim 19, characterised in that  
5 said K-tuplet of granularity is determined during a choosing operation.

21. Reception method according to Claim 19 ~~or 20~~, said original information sequence having been sent by means of a sending method according to Claim 2, characterised in that, from a granularity equal to a positive integer  $n'$  less than or equal to said integer  $n$ , said reception method includes:

10 - an operation of receiving K frequency symbols sent by means of the aforementioned transmission method;

- an extraction operation, consisting of periodically extracting one sequence out of  $2^n'$  amongst the frequencies of each of said K frequency symbols received, thus forming a reduced frequency symbol with  $2^{p-n'}$  frequencies;

- a transformation operation (E6; E10; E14), consisting of applying, to each of said K reduced frequency symbols with  $2^{p-n'}$  frequencies, a reversible transformation including a multiplication by an invertible matrix of size  $2^{p-n'} \times 2^{p-n'}$  ; and

20 - an operation of decoding (E8; E12; E16) all the K reduced frequency symbols with  $2^{p-n'}$  frequencies, thus forming a decoded information sequence.

22. Reception method according to Claim 21, characterised in that said granularity is determined during a choosing operation.

25 ~~or~~ 23. Reception method according to Claim 20 ~~or 22~~, characterised in that said choosing operation consists of choosing said granularity so as to be the greater, the better the reception quality.

24. Reception method according to Claim 20, ~~22 or 23~~, characterised in that said choosing operation consists of choosing said granularity from a look-up table giving the possible granularity values as a function of signal to noise ratios.

25. Reception method according to Claim 20, 22, 23 or 24, characterised in that said choosing operation consists of choosing said granularity from a look-up table giving the possible granularity values as a function of the distance between a sender using a sending method according to 5 any one of Claims 1 to 9 and a receiver implementing said reception method.

*a* 26. Reception method according to ~~any of Claims 19 to 25~~, characterised in that said transformation operation (E6; E10; E14) is a direct fast discrete Fourier transformation operation.

*a* 10 27. Reception method according to ~~any of Claims 19 to 26~~, characterised in that said decoding operation (E8; E12; E16) consists of decoding said set of reduced frequency symbols according to a decoding technique which is a function of said granularity.

*a* 15*a* 28. Reception method according to ~~any of Claims 19 to 27~~, characterised in that said decoding operation (E8) is a turbodecoding operation.

*a* 29. Reception method according to ~~any of Claims 19 to 27~~, characterised in that said decoding operation (E12) is a Viterbi decoding operation.

*a* 20 30. Reception method according to ~~any of Claims 19 to 27~~, characterised in that said decoding operation (E16) is a threshold decoding operation.

*a* 25 31. Device for receiving signals representing an original information sequence sent by a sending device according to ~~any one of Claims 10 to 18~~, characterised in that, from a K-tuplet of granularity equal to positive integers  $n'_1, n'_2, \dots, n'_K$  such that each integer  $n'_i$  is less than or equal to said integer  $n_i$ , said reception device has:

- transformation means (40; 50; 60), for applying, for each integer  $i$  varying from 1 to  $K$ , to said reduced frequency symbol with  $2^{p-n'_i}$  frequencies, a reversible transformation including a multiplication by an invertible matrix of size  $2^{p-n'_i} \times 2^{p-n'_i}$ ; and

30 - decoding means (44; 54; 64) for decoding all the  $K$  reduced frequency symbols with  $2^{p-n'_i}$  frequencies, thus forming a decoded information sequence.

32. Reception device according to Claim 31, characterised in that said K-tuplet of granularity is determined using choosing means.

33. Reception device according to Claim 31 or 32, said original information sequence having been sent by a sending device according to Claim 5 11, characterised in that, from a granularity equal to a positive integer  $n'$  less than or equal to said integer  $n$ , said reception device has:

- transformation means (40; 50; 60), for applying, to each of said K reduced frequency symbols with  $2^{p-n'}$  frequencies, a reversible transformation including a multiplication by an invertible matrix of size  $2^{p-n'} \times 2^{p-n'}$ ; and

10 - decoding means (44; 54; 64), for decoding all the K reduced frequency symbols with  $2^{p-n'}$  frequencies, thus forming a decoded information sequence.

34. Reception device according to Claim 33, characterised in that said granularity is determined using choosing means.

15 *a* 35. Reception device according to Claim 32 or 34, characterised in that said choosing means choose said granularity so as to be the greater, the better the reception quality.

20 *a* 36. Reception device according to Claim 32, 34 or 35, characterised in that said choosing means choose said granularity from a look-up table giving the possible granularity values as a function of signal to noise ratios.

25 *a* 37. Reception device according to Claim 32, 34, 35 or 36, characterised in that said choosing means choose said granularity from a look-up table giving the possible granularity values as a function of the distance between a sender having a sending device according to any one of Claims 10 to 18 and a receiver having said reception device.

*a* 38. Reception device according to any of Claims 31 to 37, characterised in that said transformation means (40; 50; 60) are direct fast discrete Fourier transformation means.

30 *a* 39. Reception device according to any of Claims 31 to 38, characterised in that said decoding means (44; 54; 64) decode said set of reduced frequency symbols according to a decoding technique which is a function of said granularity.

40. Reception device according to ~~any of Claims 31 to 39~~, characterised in that said decoding means (44) are turbodecoding means.

41. Reception device according to ~~any of Claims 31 to 39~~, characterised in that said decoding means (54) are Viterbi decoding means.

5 42. Reception device according to ~~any of Claims 31 to 39~~, characterised in that said decoding means (64) are threshold decoding means.

43. Digital signal processing apparatus, characterised in that it has means adapted to implement a sending method according to ~~any of Claims 1 to 10~~<sup>or 2</sup>.

10 44. Digital signal processing apparatus, characterised in that it has means adapted to implement a reception method according to ~~any of Claims 19 to 30~~.

45. Digital signal processing apparatus, characterised in that it has a sending device according to ~~any of Claims 10 to 18~~<sup>or 11</sup>.

15 46. Digital signal processing apparatus, characterised in that it has a reception device according to ~~any of Claims 31 to 42~~.

47. Telecommunications network, characterised in that it has means adapted to implement a sending method according to ~~any of Claims 1 to 9~~<sup>or 2</sup>.

20 48. Telecommunications network, characterised in that it has means adapted to implement a reception method according to ~~any of Claims 19 to 30~~.

49. Telecommunications network, characterised in that it has a sending device according to ~~any of Claims 10 to 18~~<sup>or 11</sup>.

50. Telecommunications network, characterised in that it has an information reception device according to ~~any of Claims 31 to 42~~.

25 51. Mobile station in a telecommunications network, characterised in that it has means adapted to implement a sending method according to ~~any of Claims 1 to 9~~<sup>or 2</sup>.

52. Mobile station in a telecommunications network, characterised in that it has means adapted to implement a reception method according to ~~any of Claims 19 to 30~~.

53. Mobile station in a telecommunications network, characterised in that it has a sending device according to ~~any of Claims 10 to 18~~<sup>or 11</sup>.

54. Mobile station in a telecommunications network, characterised in that it has a reception device according to ~~any of Claims 31 to 42.~~

55. Information storage means which can be read by a computer or microprocessor storing instructions of a computer program, characterised in that it implements a sending method according to ~~any of Claims 1 to 9.~~

56. Information storage means which can be read by a computer or microprocessor storing instructions of a computer program, characterised in that it implements a reception method according to ~~any of Claims 19 to 30.~~

10 totally, and which can be read by a computer or microprocessor storing instructions of a computer program, characterised in that it implements a sending method according to ~~any of Claims 1 to 9.~~

15 57. Information storage means which is removable, partially or totally, and which can be read by a computer or microprocessor storing instructions of a computer program, characterised in that it implements a reception method according to ~~any of Claims 19 to 30.~~

20 58. Computer program product, characterised in that it comprises software code portions for implementing a sending method according to ~~any of~~  
Claim\$ 1 to 9.

60. Computer program product, characterised in that it comprises software code portions for implementing a reception method according to ~~any of~~  
Claim\$ 19 to 30.